The QIE Digitizer for use in the Tevatron IPM

- Requirements
- Overview of the QIE
- Bench measurements of QIE
- Primary Ionization Statistics, MCP Gain, and Anode Board
- Simulations of Beam Profile Reconstruction
- Conclusions

TeV IPM Review
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Requirements

• High rate current−integration and digitization for separate observation of proton and anti−proton bunches at the E0 location.

• Dead−timeless operation for bunch−to−bunch observations.

• Better than 10% resolution on beamwidth, in the light of 10::1 proton−pbar signal strength.

• To achieve low noise, digitizer will be placed in the tunnel. So it must be rad−tolerant.

• Easy to use, low overhead, and readily available.

Charge Integrating Encoder (QIE)

- Developed at Fermilab and used in KTeV, CDF, MINOS, and now CMS

- Charge Integrating ASIC with no deadtime. This is done by exploiting parallel circuitry. 2 bit "Cap ID" used to tag the QIE's internal parallel circuitry.

- Can operate in frequency range 7 − 53 MHz

- Wide dynamic range readout with 5 bit mantissa, 2 bit exponent

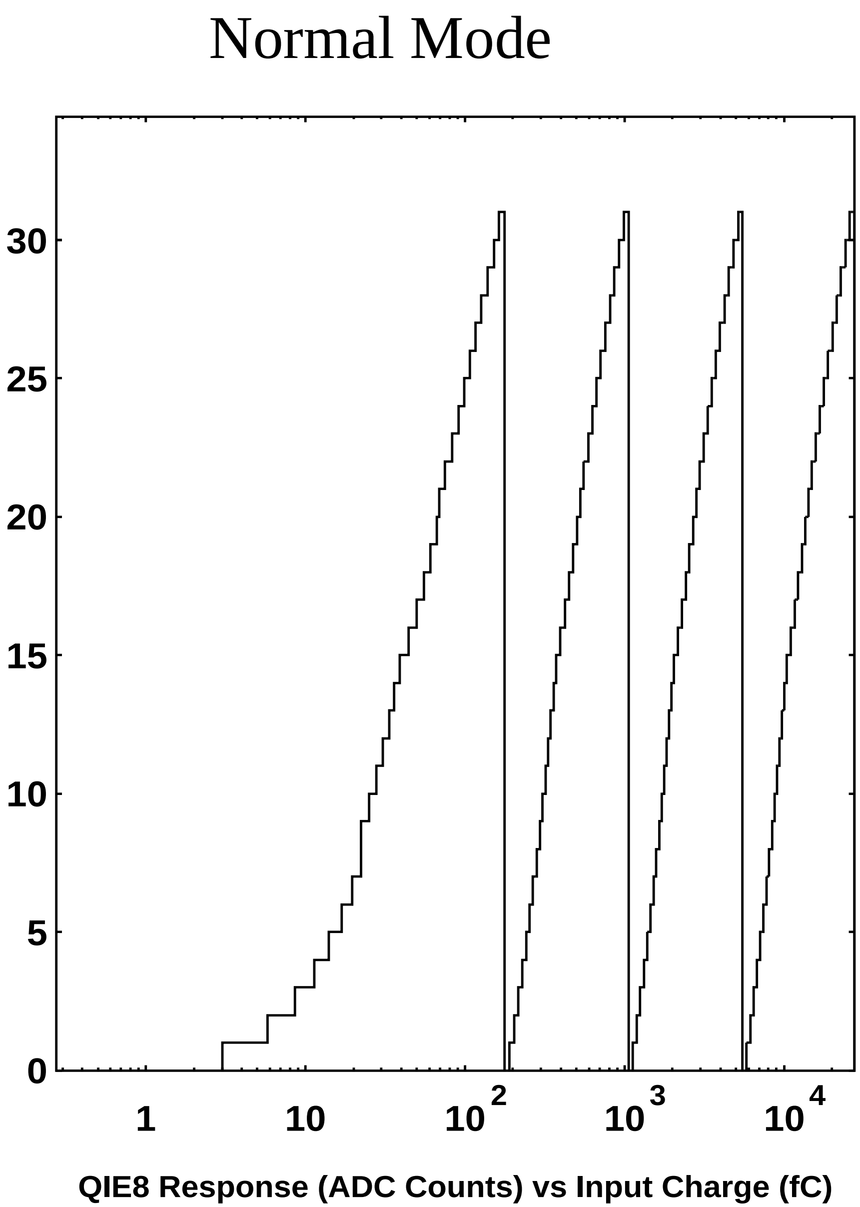
Three (user−selectable) modes of operation:

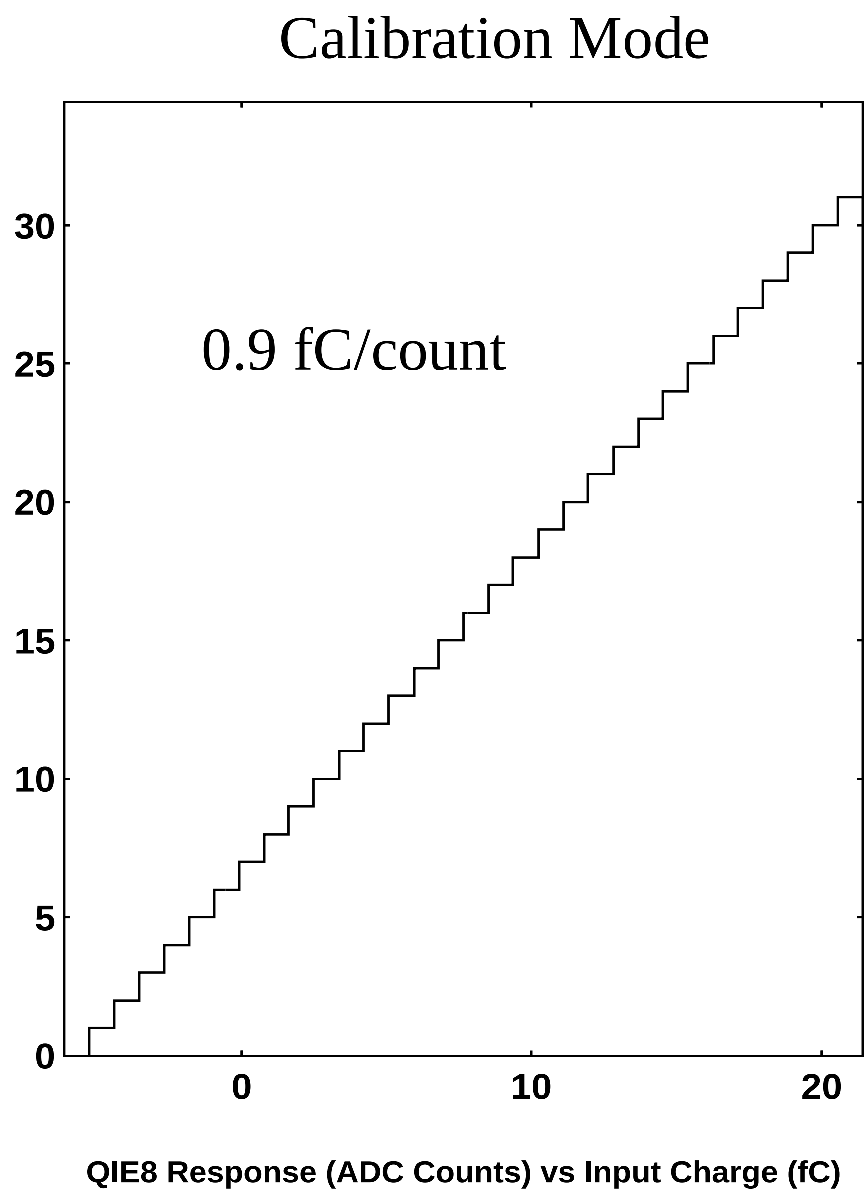
"Normal Mode"	:	−2.6 fC/count with logarithmic sensitivity
"Calibration Mode"	:	−0.9 fC/count with linear sensitivity
"Inverted Mode"	:	1.0 fC/count with logarithmic sensitivity

- Can achieve noise of O(1fC)

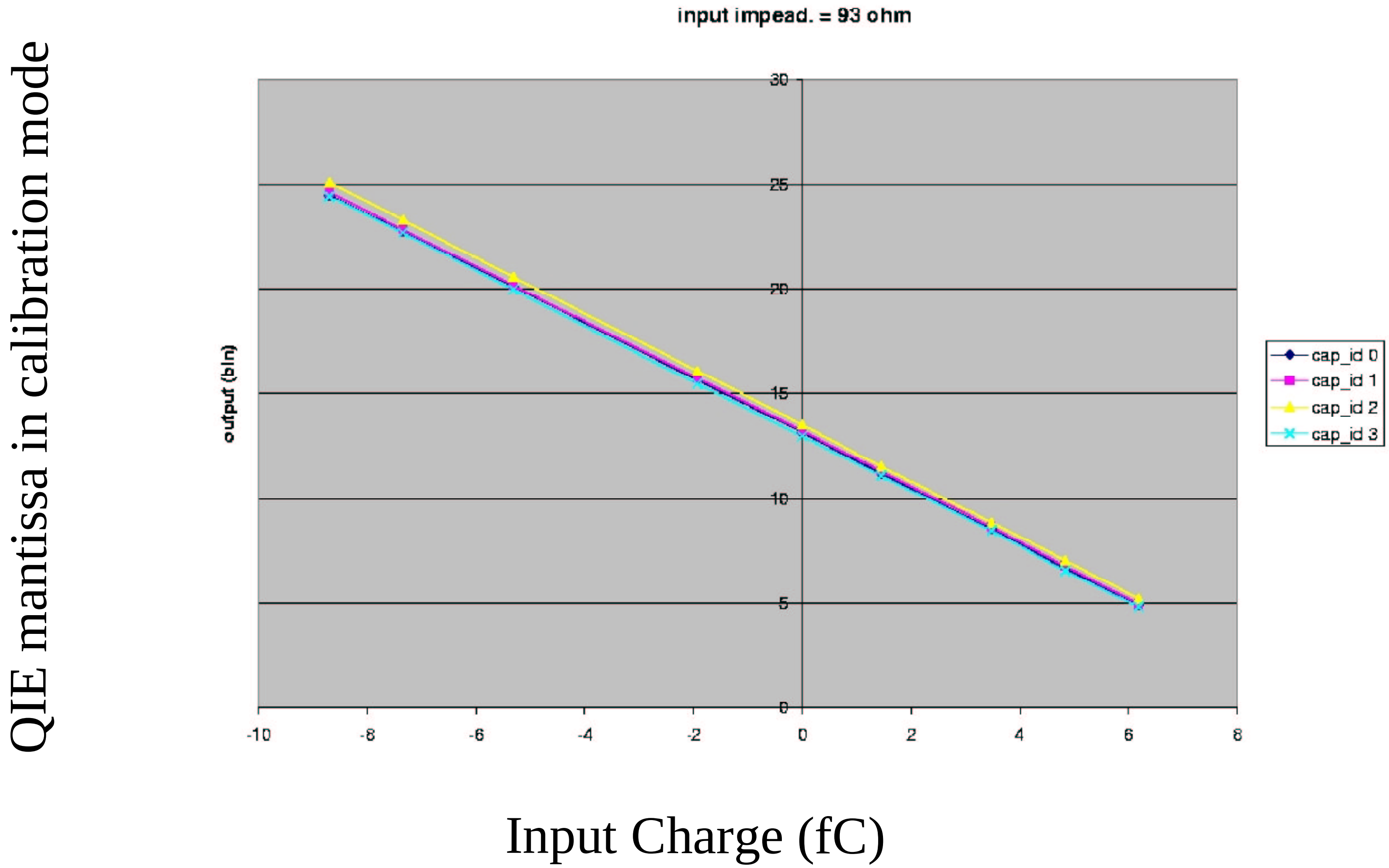
- Disadvantage: relatively large package, so "low channel density"

Idealized Illustration of QIE Response vs Charge

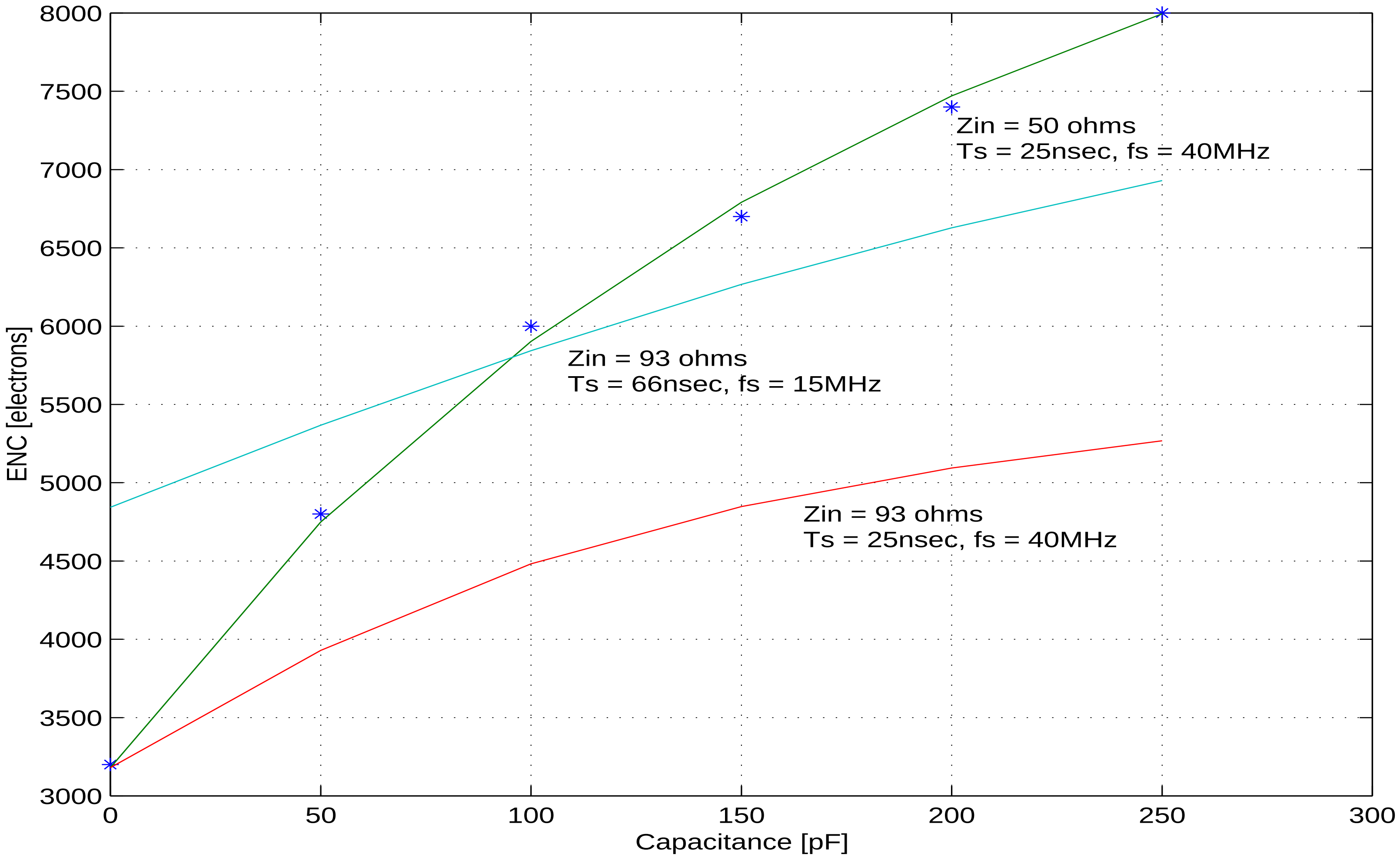




Test Bench Measurements of QIE



Performed at using 4−channel QIE board (built for CKM) in FCC−3W



- Noise depends on user−selectable (50 or 93 Ohm) input impedence, frequency, and total capacitance (i.e. Cable length)

- Noise appears to be incoherent ("white noise")

- Need to be careful in cabling of signal, signal return, and shielding (experience from CMS)

Primary Statistics, MCP Gain, and Anode Board

Rough Estimate of Primary Ionization:

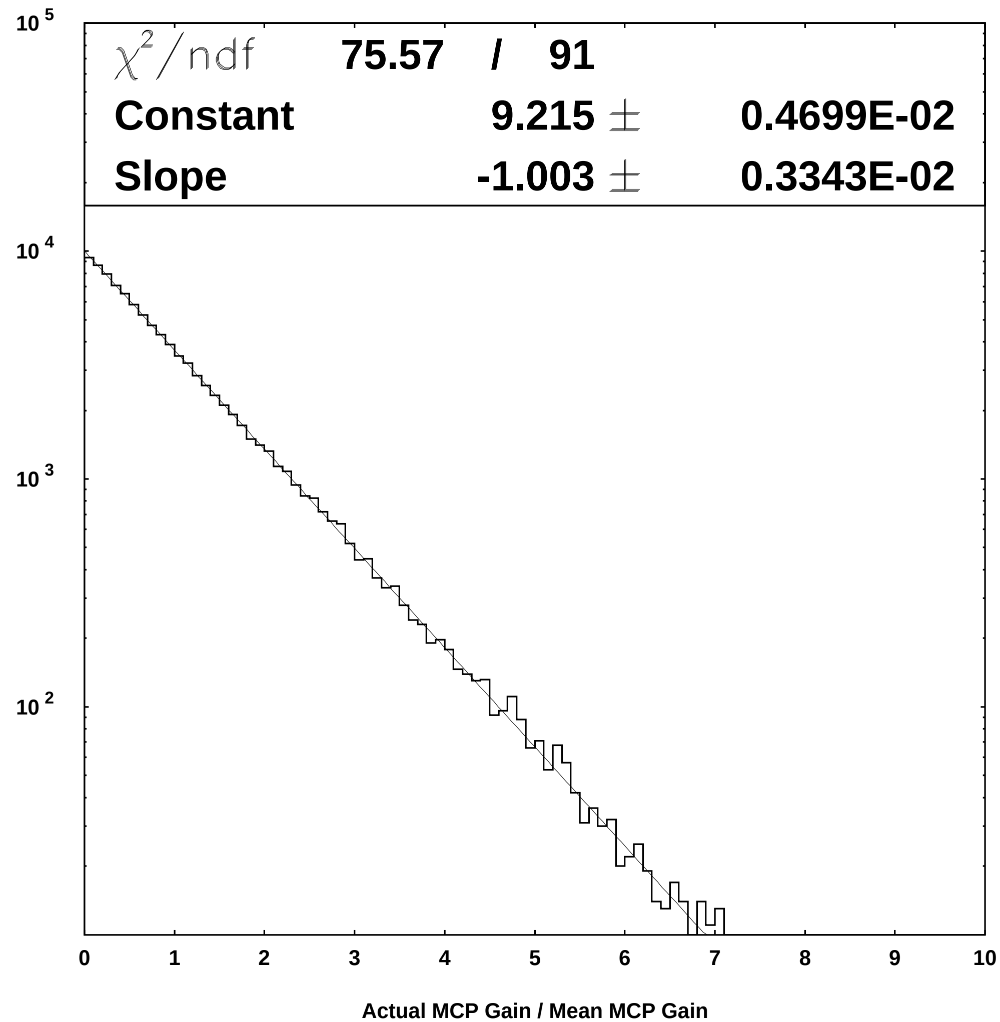
(10 ionizations/cm/atm) x
(10 cm detector length) x
(10^{-8} Torr) x
(2.7 x 10^{11} protons/bunch) =

1000 ionizations per proton bunch

Can be adjusted by changing the local gas pressure

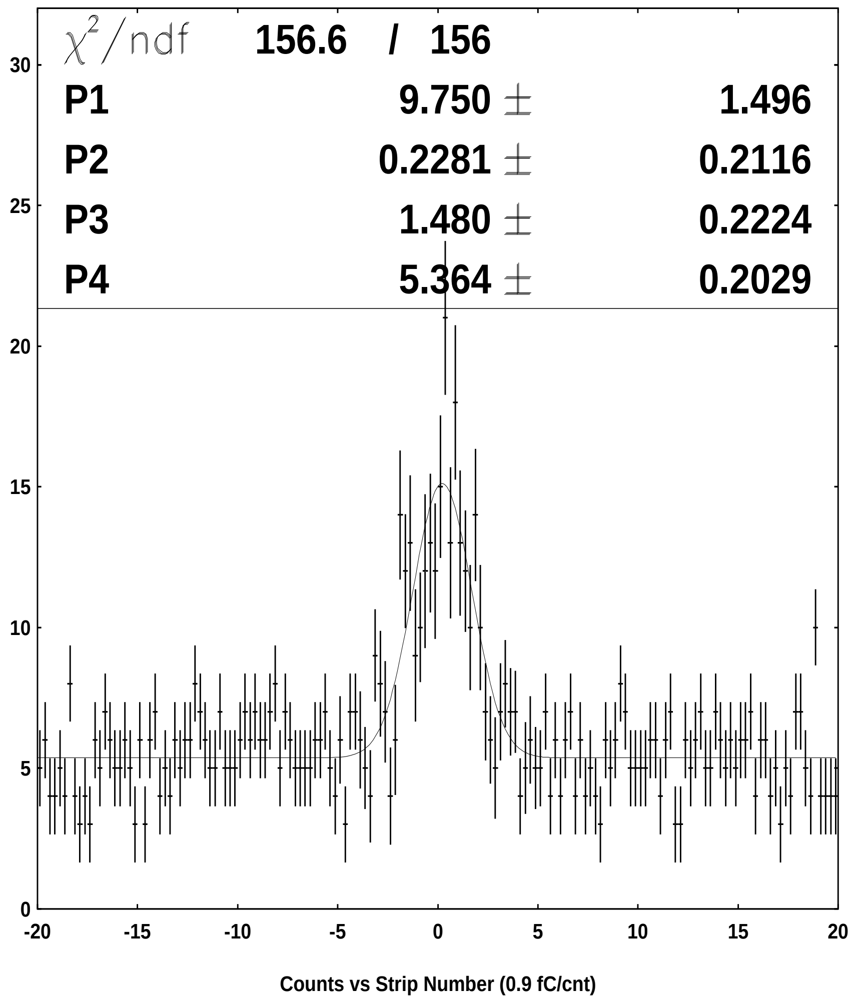
Anode Board: ¼ mm strip spacing

MCP: Mean gain can be adjusted from 1K − 10K with exponential gain dispersion

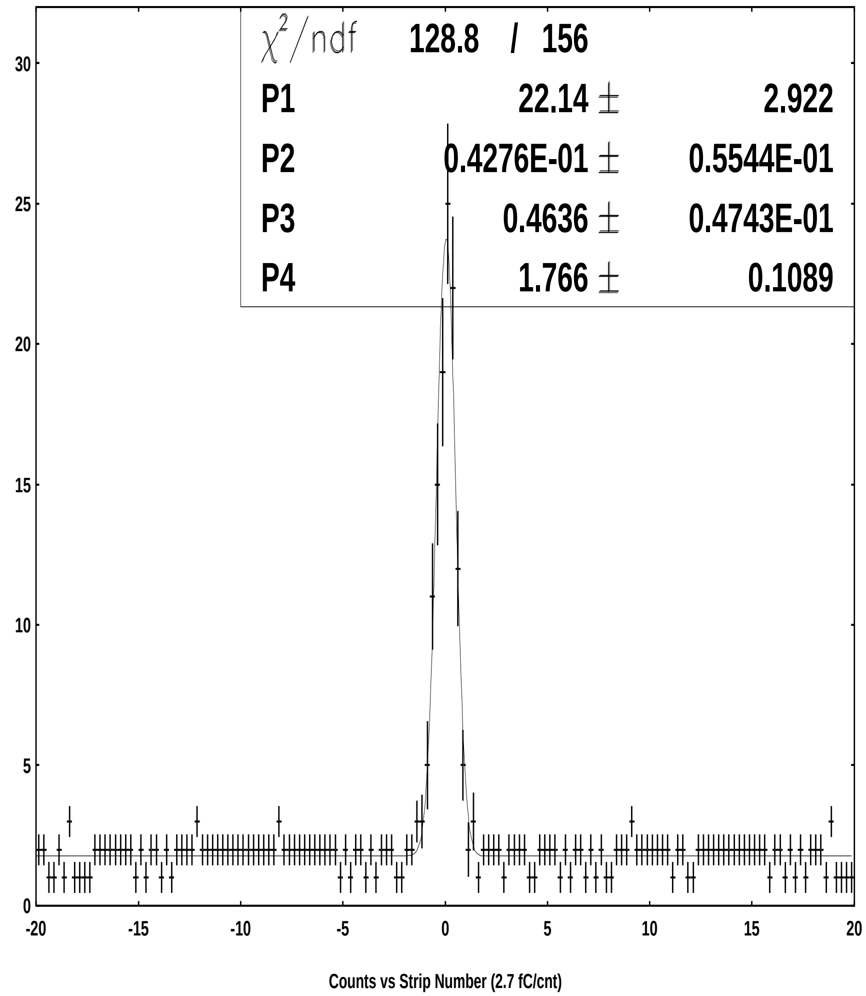


Examples of Beam Profile Reconstruction using QIE

Calibration Mode,
Gain=3000, Nprimary=300, at Injection



Normal Mode,
Gain=10000, Nprimary=300, at Flattop



Electronic noise of 1 fC used in all simulations shown

We have flexibility in choosing the QIE mode and MCP Gain

- In calibration mode, the maximum charge/channel ~ 28 fC. This is the QIE's dynamic range limitation.

- In normal mode, the maximum charge/channel ~ 200 fC.
This is the MCP's saturation limit.

- The QIE mode and MCP gain we'll use depends on Nprimary and TeV operation (injection or flattop).

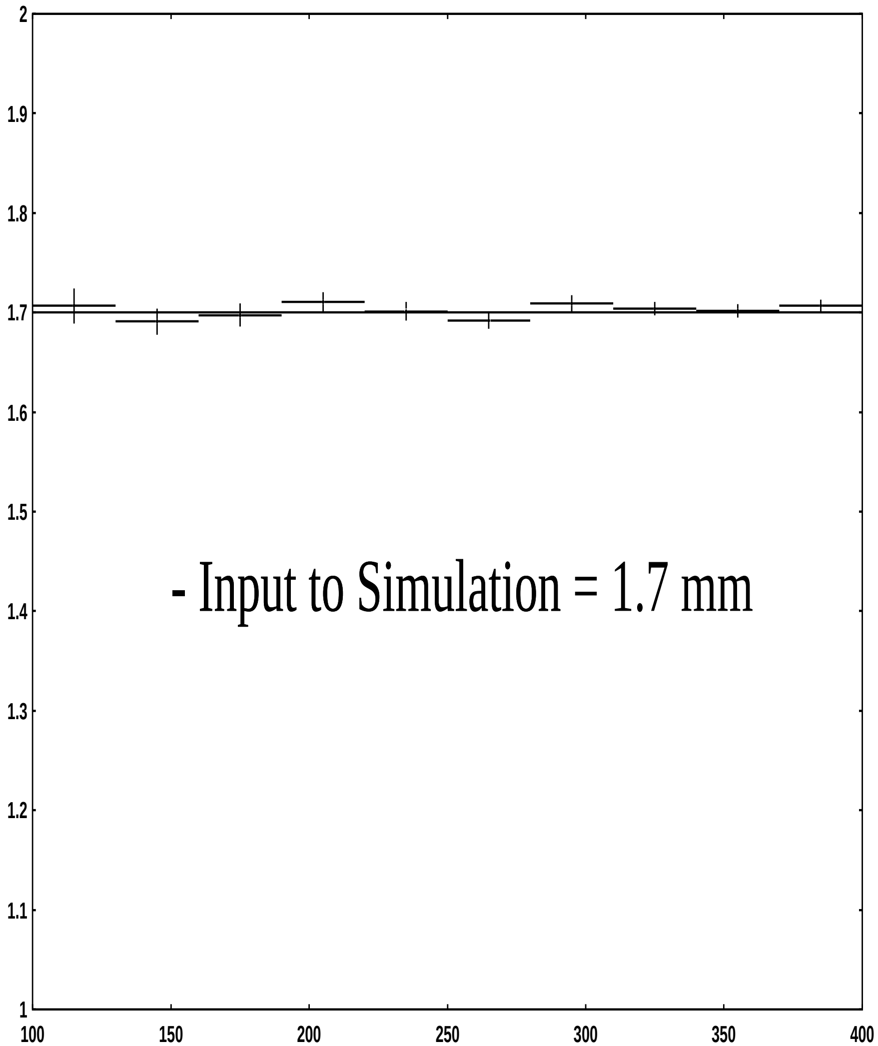
- Nprimary can be increased by local gas pressure.

- We can numerically add samples together to improve measurements.

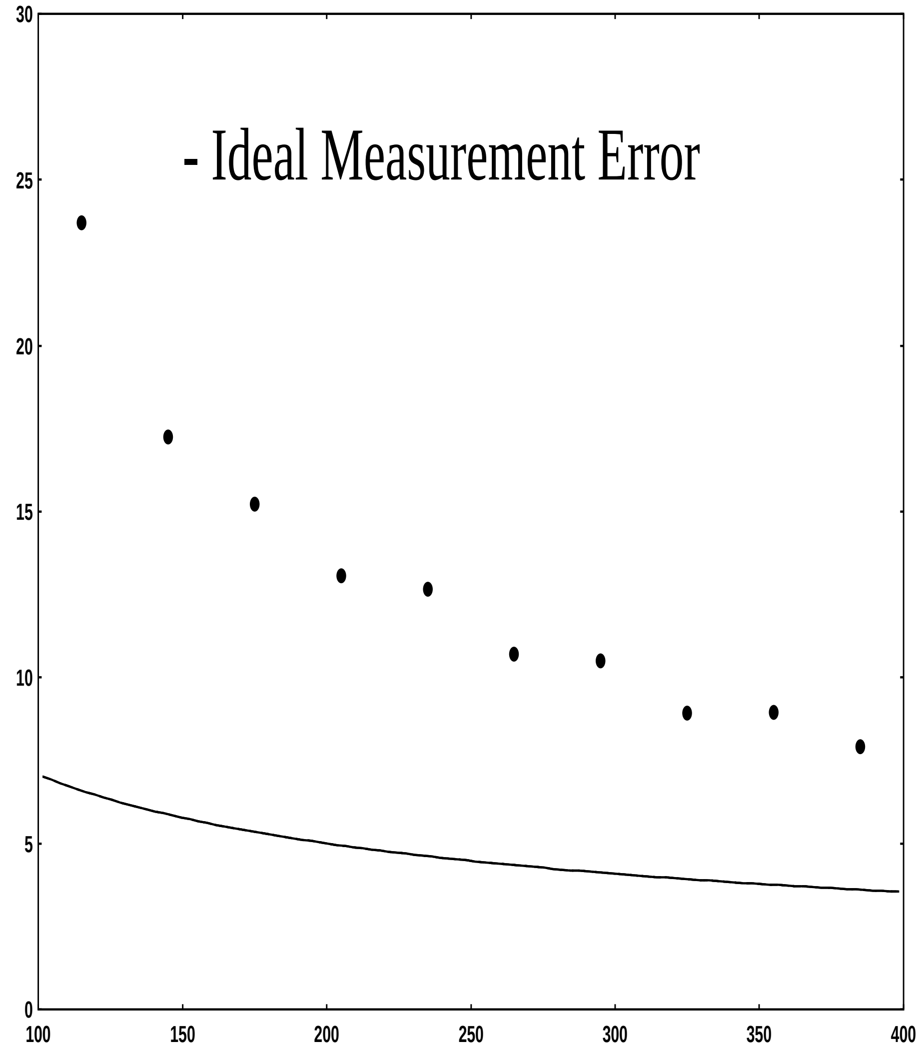
These parameters will determine how well we determine the beam width.

Possible Scenario for Pbar Measurement at TeV injection

Calibration Mode and MCP Gain=3000



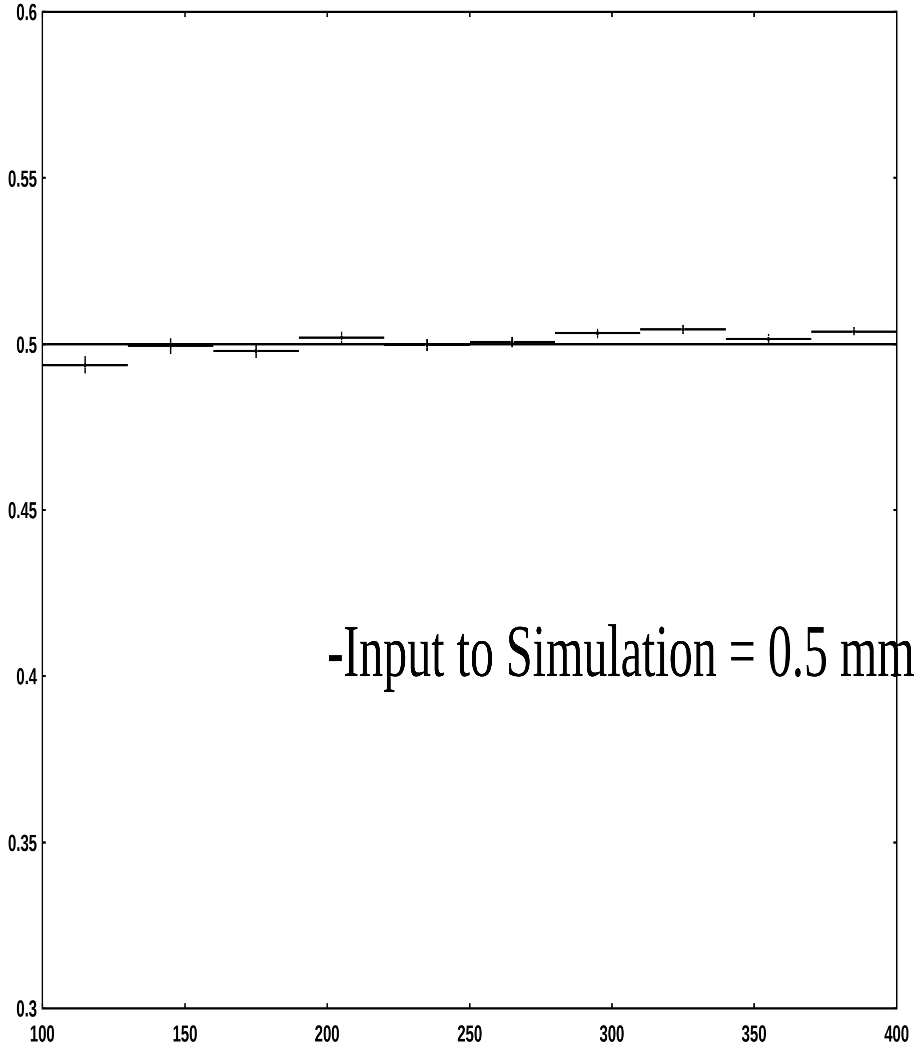
Reconstructed Beam Width (mm) vs Number of Primary Ionizations



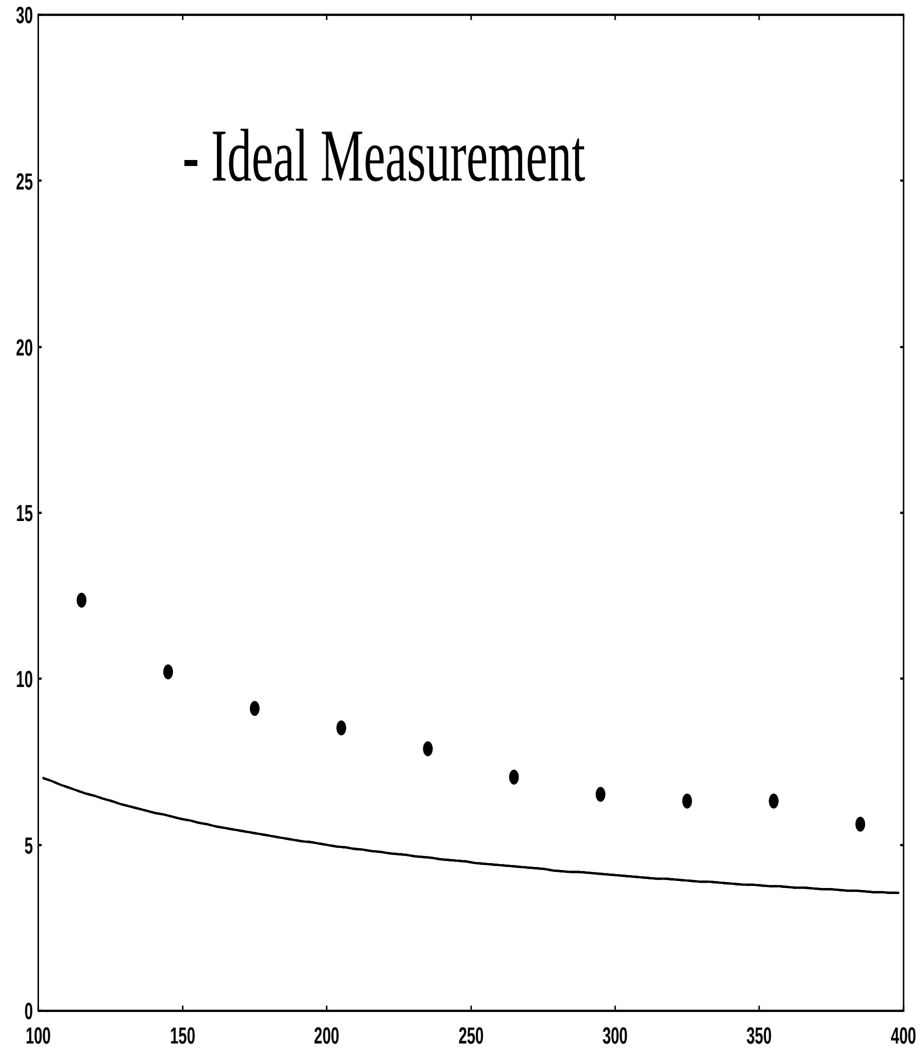
Beam Width Error (%) vs Number of Primary

Possible Scenario for Pbar Measurement at TeV Flat top

Normal Mode and MCP Gain=10000



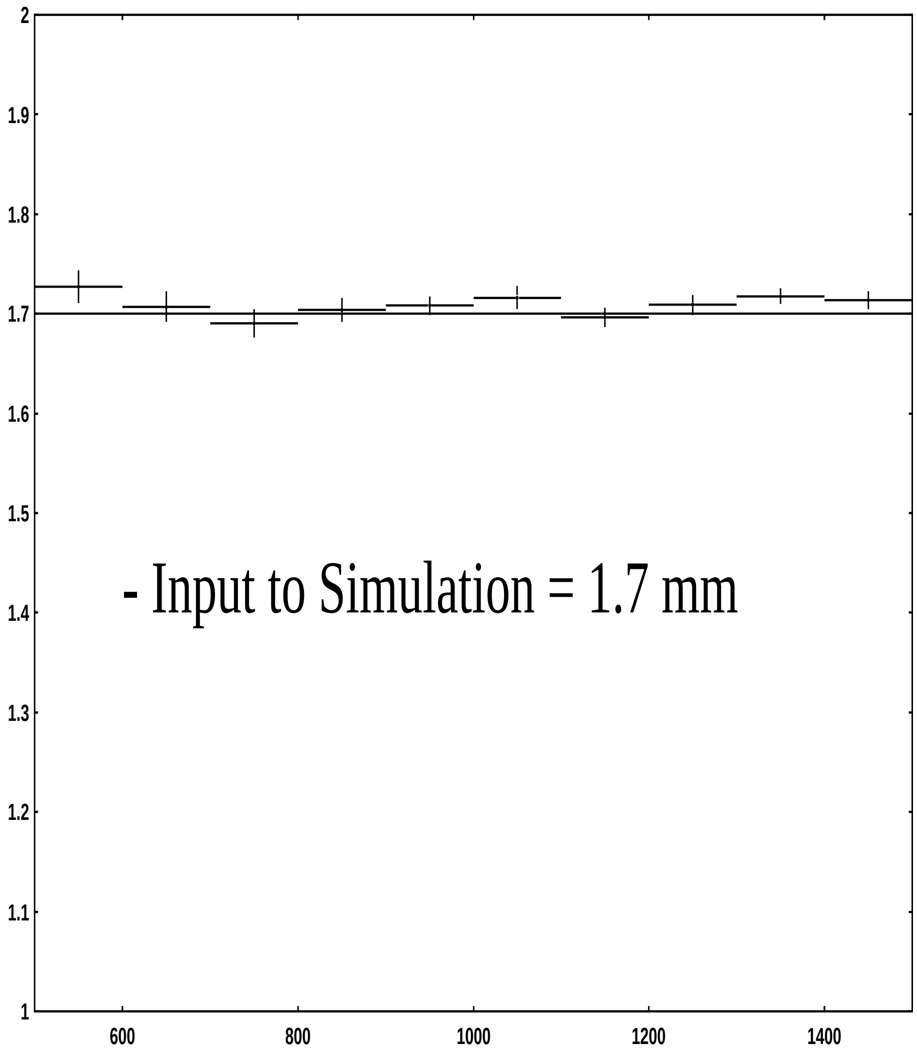
Reconstructed Beam Width (mm) vs Number of Primary



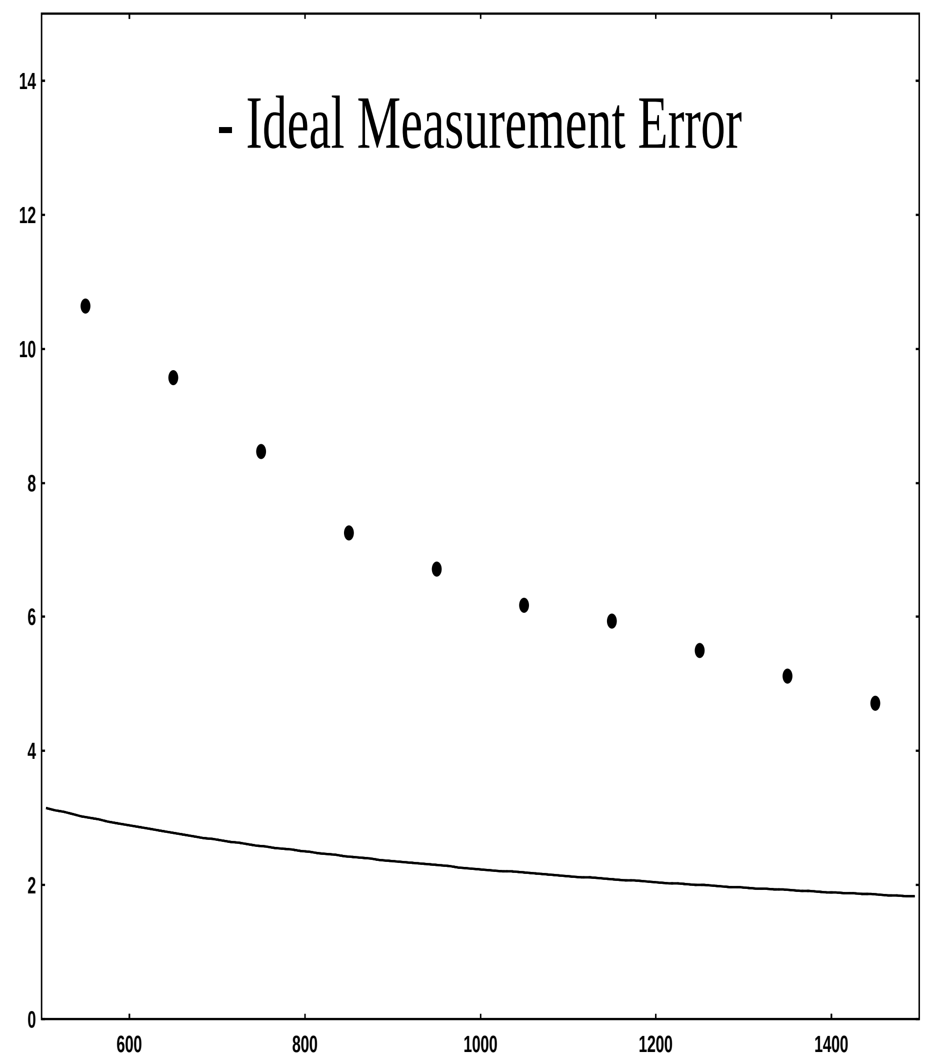
Beam Width Error (%) vs Number of Primary

Possible Scenario for Proton Measurement at TeV Injection

Calibration Mode and MCP Gain=1000



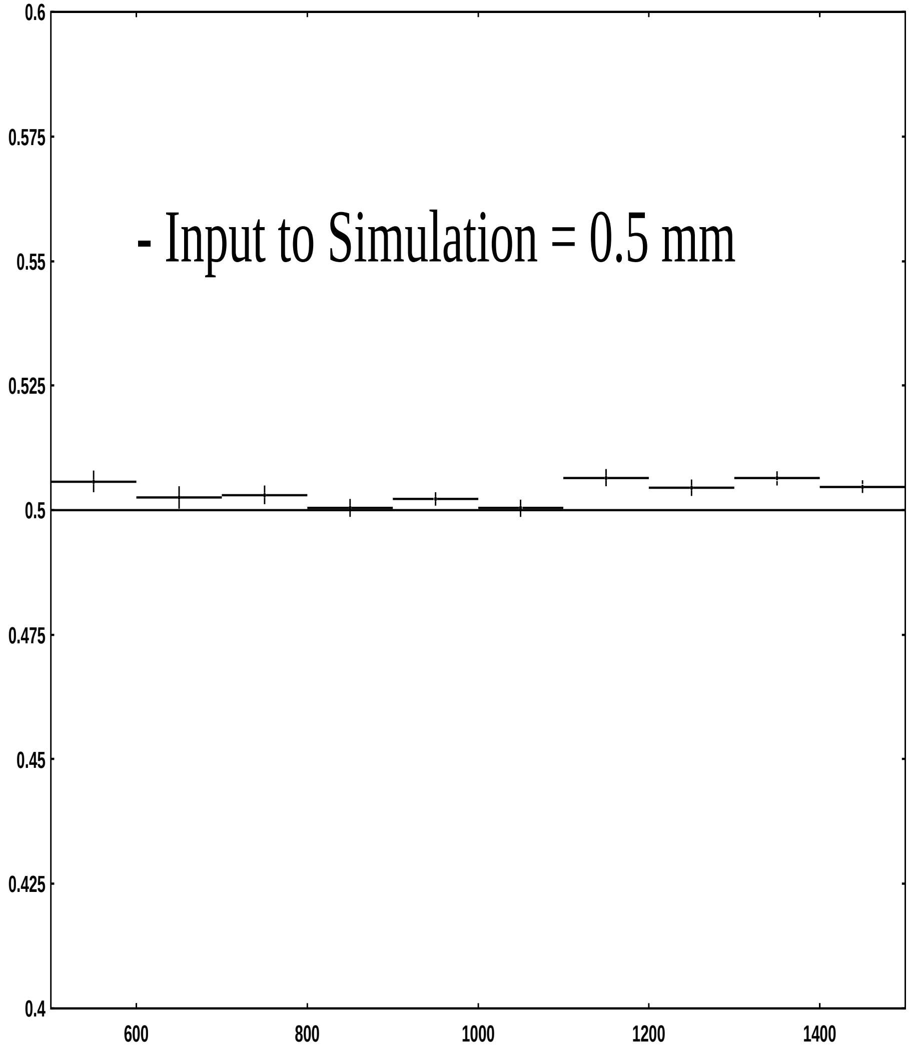
Beamwidth Measurement (mm) vs Number of Primary



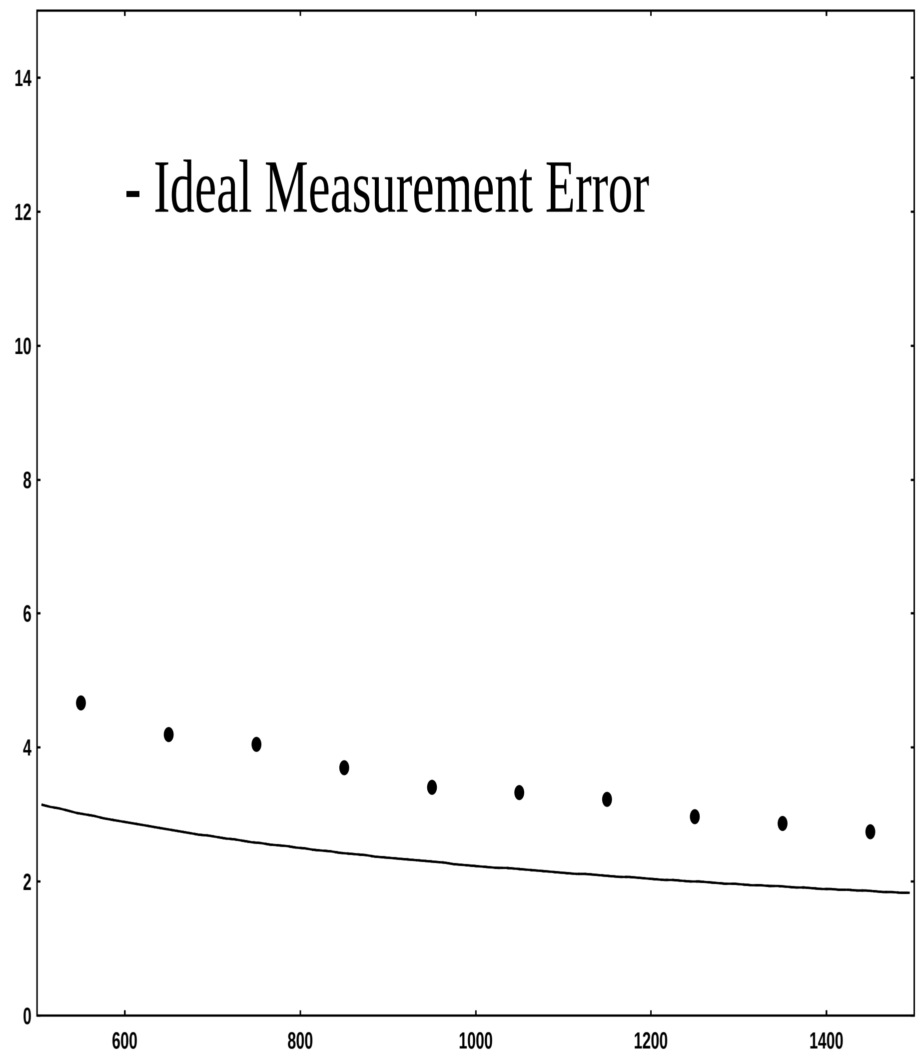
Beam Width Error (%) vs Number of Primary

Possible Scenario for Proton Measurement at TeV Flattop

Normal Mode and MCP Gain=10000



Beam Width (mm) vs Number of Primary



Beam Width Error (%) vs Number of Primary

Conclusions

The QIE was designed for use in other HEP experiments, with requirements often very different than ours. In spite of this, simulations show a 10% or better beamwidth measurement per bunch.

QIE chips are available as (free) spares from CMS QIE production run.

Main disadvantages are large packaging (so low channel density), and potentially complex cabling between MCP and QIE.

The QIE has important advantages: easy to use, low overhead, robust operation, lots of local expertise (KTeV, CDF, Minos, CMS), and low development time.

Considering all these factors, we believe the QIE is the right device to use.